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Electromagnetic Radiation Experiments with Transmitting, Contra-Wound Toroidal Coils

H. D. Froning,[a]* G. D. Hathaway[b], B. Cleveland[b]

[a] PO Box1211, Malibu CA, 90262, USA
[b]Hathaway Consulting Services, 1080 19th Sideroad, King City, L7B1KS, Ontario, Canada

Abstract

Except for Quantum Electrodynamics, there has been no real extension of Maxwell's classical electromagnetic (EM) field theory since his electromagnetic EM field equations were developed in 1864. These equations describe the behavior of vector fields of low (U1) Lie group symmetry. In this respect, Terence W. Barrett has used topology, group and gauge theory, to extend Maxwell theory into tensor fields of higher symmetry form: SU (2), SU (3), and higher, that describe the behavior of specially conditioned EM fields. One of Barrett's ways of emitting SU(2) EM fields was driving alternating current through toroidal coils at any of the resonant frequencies that will occur for a specific toroid geometry. Experiments to explore the possibility of achieving such resonant frequencies and SU(2) EM emissions will be described.

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1. Introduction

In 1864 Maxwell described a unification of electricity and magnetism with equations that later followers distilled into the four equations now known as the "Maxwell equations" that conform to the laws of electromagnetism (EM) formulated by Gauss, Ampere, Coulomb and Faraday. In the 1950's Feynman and others made Maxwell's classical EM theory compatible with Quantum theory and resulted in Quantum Electrodynamics (QED). QED was consistent with both quantum mechanics and special relativity and precisely predicted interactions between radiation and matter. But, despite its reformulation

* Corresponding author. Tel.: *310-459-5291*; fax: +0-000-000-0000 .
E-mail address: froning@infomagic.net .

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from quaternionic to vector algebra form, no extension of Maxwell theory has been made during its 146 years of life - despite the inability to accurately explain many observed EM phenomena.

In most cases, EM radiation fields are correctly and adequately described by the classical Maxwell equations which is a theory of U(1) symmetry form. However, in special topologies or situations or boundary conditions, radiation fields are produced that require an extension of Maxwell theory to higher symmetry. Addressing such situations, Barrett [1] has used topology, group and gauge to derive SU(2) EM radiation fields for those cases of specially conditioned radiation. A specific SU(2) EM radiation field proposed by Barrett is that which is emitted by toroidal coils when alternating current flows through them at any of the resonant frequencies that will occur for a specific toroid geometry. Toroidal coils have been constructed and tested, and. this paper summarizes testing results.

2. Maxwell Equations For Ordinary And Conditioned Em Fields

Using group theoretic methods, EM radiation fields of SU(2) symmetry can be created by special conditioning of conventional U(1) EM fields. Table 1 shows Maxwell's (U(1) symmetry) four equations describing electric field strength (***E***), magnetic flux density (***B***) and current density (***J***). The ***E*** and ***B*** fields of force can be related to a "magnetic vector potential" (***A***) and "scalar electric potential" (φ). These potentials are unphysical and mere mathematical conveniences in terms of the U(1) field theory. However, in the SU(2) field theory, the potentials ***A*** and φ do have physicality [1]. Table 2 shows extended Maxwell equations that describe propagation of specially conditioned SU(2) EM fields. These Maxwell Equations are based on tensor, rather than vector field terms, and include ***E*** and ***B*** fields as U(1) Maxwell Equations do. But they include additional terms: (i) which can be viewed as the square root of -1 or as an orthogonal rotation occurring in x, y, z, ct spacetime; electron charge (q); and added interactions ***A x E, A x B, A • E***; and ***A• B*** ([1], pp 145-147). These tensors, or matrices function as operators obeying non-commutative, non-Abelian algebra. So, ***A x B*** does not = ***B x A*** for SU(2) fields.

The well known Lorentz force (***F***) arises from an electromagnetic interaction that involves ***B*** and ***E*** fields and the velocity (***v***) of charge clusters with charge (e). Table 3 shows force equations for both the U(1) EM vector fields in terms of the magnetic vector potentials and electric scalar potentials that underlie these U(1) vector fields and SU(2) tensor fields in terms of the vector and scalar potentials and it is noted that extra terms are in the SU(2) force equation. Thus, SU(2) field interaction forces can be different in magnitude and direction than U(1) field forces.

3. SU(2) EM Radiation From Toroidal Coils At Resonant Frequencies

Barrett [2] describes one way of emitting SU(2) EM radiation. It is driving alternating current through toroidal coils at any of the resonant frequencies that will occur for the specific toroid geometry. Figure 1 shows the EM field pattern of a transmitting toroid as a U(1) A potential field overlapping in polarity across the toroid – with a set of equipotential lines of φ_1 pattern and another set of equipotential lines of φ_2 pattern. Also shown is a resonant frequency when the phase is such that (φ_1- φ_2) is maximal, and the various resonant radio frequencies that can occur for a given toroid. At every resonant frequency, the alternating difference in the U(1) potential fields is maximized for the whole toroid. An SU(2) potential field is maximized as well and this results in a maximum transmitted signal.

It was expected that resonant frequencies for radiating toroids would be revealed at the frequencies where the phase of alternating current would reverse and feed-point impedance would peak. Toroidal coils configured to emit SU(2) EM radiation were tested at Hathaway Consulting Services. Frequency sweeps revealed resonances for every tested toroid. Figure 2 shows good agreement between measured resonant frequencies and resonant frequencies predicted by Barrett [2, 3] for SU(2) field emission. The sweeps also revealed that EM fields emitted from each toroid would dramatically increase in strength within those narrow frequency bands where the resonances occurred.

Table 1. Maxwell Equations for Ordinary U(1) EM Fields.

Gauss' Law	$\nabla \bullet \boldsymbol{E} = \boldsymbol{J}_0$
Ampere's Law	$\frac{\partial \boldsymbol{E}}{\partial t} - \nabla \times \boldsymbol{B} - \boldsymbol{J} = 0$
Coulomb's Law	$\nabla \bullet \boldsymbol{B} = 0$
Faraday's Law	$\nabla \times \boldsymbol{E} + \frac{\partial \boldsymbol{B}}{\partial t} = 0$

$$E = -\frac{\partial A}{\partial t} - \nabla\phi, \quad B = \nabla \times A$$

Table 2. Maxwell Equations for Specially Conditioned SU(2) tensor EM Fields [1].

$\nabla \bullet \boldsymbol{E} = \boldsymbol{J}_0 - iq(\boldsymbol{A} \bullet \boldsymbol{E} - \boldsymbol{E} \bullet \boldsymbol{A})$
$\frac{\partial \boldsymbol{E}}{\partial t} - \nabla \times \boldsymbol{B} - \boldsymbol{J} + iq[\boldsymbol{A}_0, \boldsymbol{E}] - iq(\boldsymbol{A} \times \boldsymbol{B} - \boldsymbol{B} \times \boldsymbol{A}) = 0$
$\nabla \bullet \boldsymbol{B} + iq(\boldsymbol{A} \bullet \boldsymbol{B} - \boldsymbol{B} \bullet \boldsymbol{A}) = 0$
$\nabla \times \boldsymbol{E} + \frac{\partial \boldsymbol{B}}{\partial t} + iq[\boldsymbol{A}_0, \boldsymbol{B}] = iq(\boldsymbol{A} \times \boldsymbol{E} - \boldsymbol{E} \times \boldsymbol{A}) = 0$

Noting that, unlike fields of Table 1, these fields are tensor (matrix operator) fields not vector fields**.**

TABLE 3. Lorentz Force comparison for U(1) EM and SU(2) EM Fields [1].

U(1) Lorentz Force	$\mathscr{F} = e\mathbf{E} + ev \times \mathbf{B} = e\left(-\frac{\partial \mathbf{A}}{\partial t} - \nabla\phi\right) + ev \times \left(\left(\nabla \times \mathbf{A}\right)\right)$
SU(2) Lorentz Force	$\mathscr{F} = e\mathbf{E} + ev \times \mathbf{B} = e\left(-\left(\nabla \times \mathbf{A}\right) - \frac{\partial \mathbf{A}}{\partial t} - \nabla\phi\right) + ev \times \left(\left(\nabla \times \mathbf{A}\right) - \frac{\partial \mathbf{A}}{\partial t} - \nabla\phi\right)$

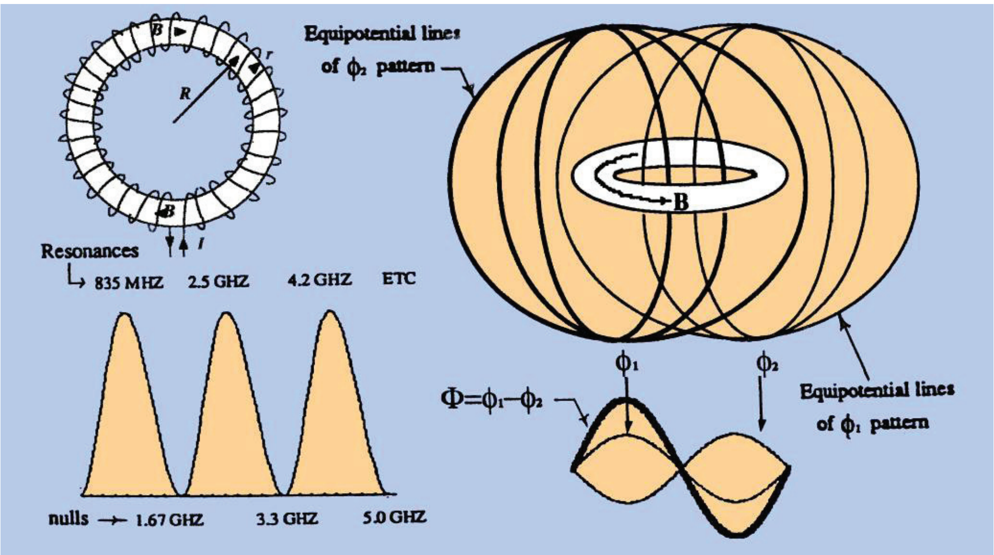

Figure 1. Potential patterns surrounding transmitting toroidal coils.

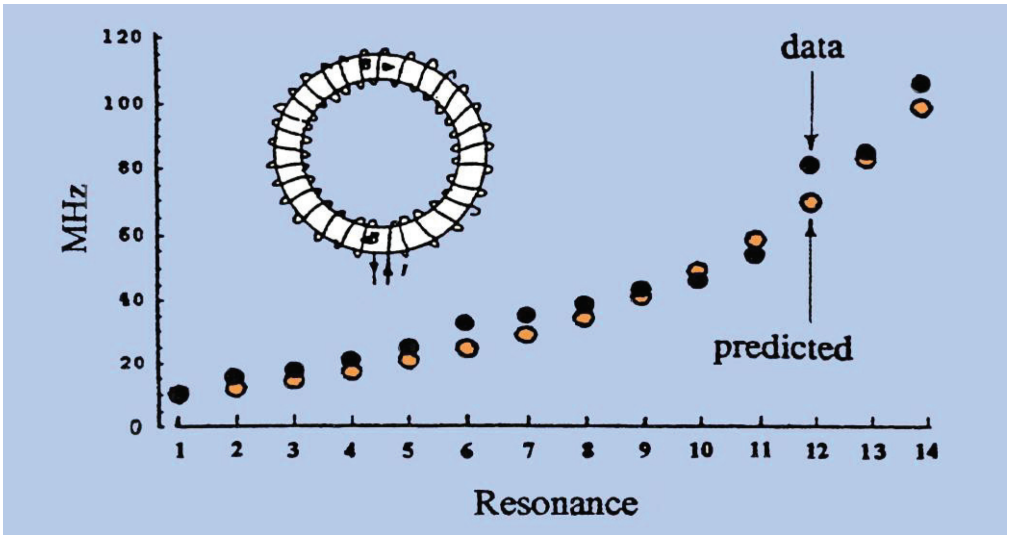

Figure 2. Good agreement between predicted and measured resonant frequencies.

The encouraging initial observations resulted in testing of 4 different toroid configurations shown in Figure 3. They typified variations in toroid major and minor diameter and coil winding density; and included asymmetric shapes. All toroids embodied contra-wound (caduceus) coils whose two interwoven wires make the same pattern as DNA strands. This allowed a current-adding mode, where equal currents flow in the 2 wires in the same direction through the coil; and a current-opposing mode, where equal current flowed in each wire in opposite directions. And, magnetic field probes confirmed that no magnetic field was induced inside each coil for this current-opposing mode.

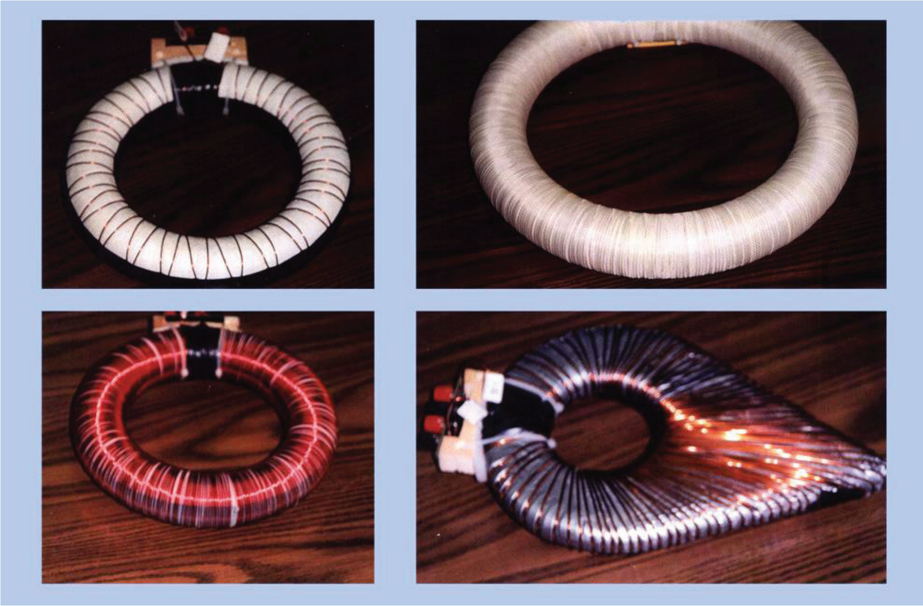

Figure 3. Various contra-wound caduceus toroids that were tested in second test series.

Radio-Frequency sweeping with equipment such as that shown in Figure 4 was conducted to find all resonant frequencies existing in the 400 KHz to 110 MHz range for each toroid. This was done for both current-adding and opposing modes of operation. Then, for at least one resonant frequency for each toroid, magnetic field strength was measured on the surface of (and, in the vicinity of,) each toroid for the current-adding and current-opposing modes.

Figure 4. Typical equipment (HP impedance analyzer and plotter) for detecting resonant toroid frequencies.

Figure 5 shows the response of the larger diameter toroid to flowing alternating current in it at frequencies from 400 KHz to 110 MHz for current-adding and current-opposing modes. Shown are many resonances occurring over the frequency spectrum in current-adding mode. Fewer (but much stronger) resonances occur in current-opposing mode.

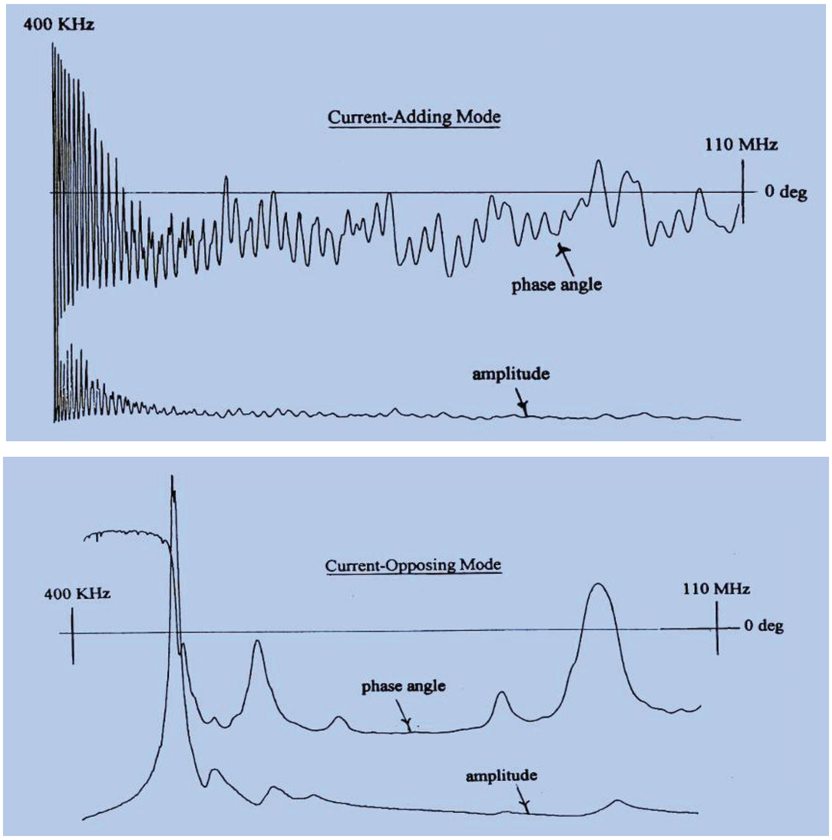

Figure 5. Larger diameter toroid response to frequency in current-adding and current-opposing modes.

Figure 6 shows the magnetic probe used to measure the vertical component of magnetic field intensity at locations on and near the surface of each toroid when the toroid was radiating at resonant frequency. It must be noted that this magnetic probe could not detect the individual undulations of any SU(2) A fields emitted by the toroids. But probe presence would cause symmetry breaking of any SU(2) A fields into U(1) B fields that the U(1) probe could detect.

Figure 7 shows steep magnetic field gradients forming over tightly-wound toroidal coils that may be emitting SU(2) EM radiation. Shown is higher magnetic field peak for the smaller diameter toroid in current-opposing mode and higher magnetic field peak for the larger diameter toroid in a current-adding mode. This could be due to different toroid diameters or different resonant frequencies or both. Of interest were current-opposing modes of operation for the toroids. For, despite no net current flow or magnetic field inside the coils, magnetic fields formed outside them for this mode. Such field patterns appear impossible for ordinary U(1) EM fields - but they are possible for higher order SU(2) EM fields. Also of interest, was formation of circumferential standing waves of magnetic energy over toroids in a current-adding mode. Eight peaks and nulls occurred for standing waves formed on the smaller diameter toroid surface. Ten peaks and nulls occurred for similar standing waves that formed over the larger toroid's surface.

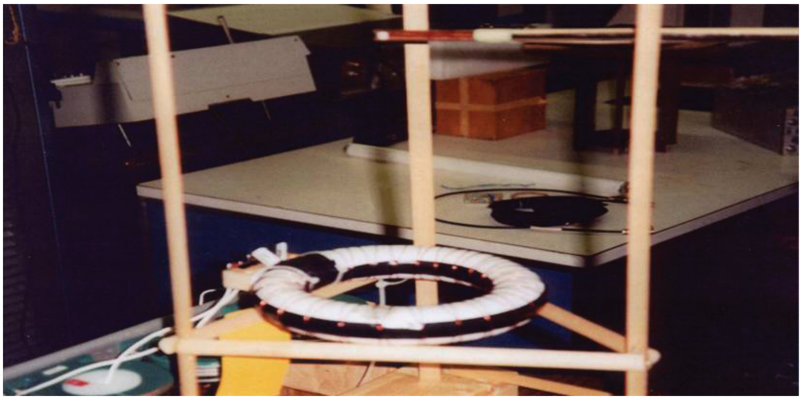

Figure 6. Magnetic probe used to measure magnetic fields generated by transmitting toroids at resonant frequencies.

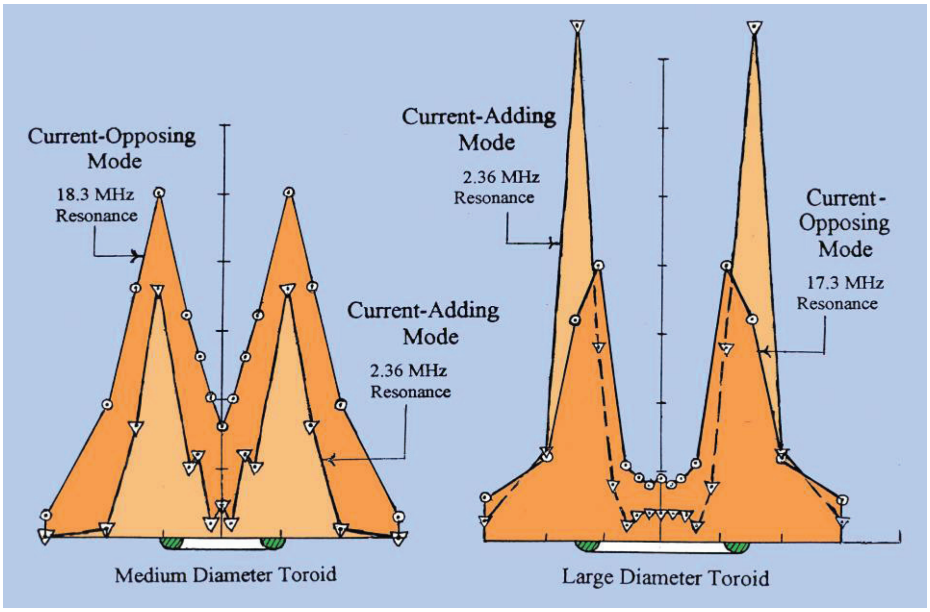

Figure 7. Steep magnetic field gradients forming in the radial direction over tightly-wound toroidal coils.

Figure 8 shows EM magnetic field energy focused into a 'forward direction' from a planar, asymmetric, teardrop-shaped toroidal coil at one of its several resonant frequencies for a current-opposing mode. Such forward focusing might be favorable for applications such as supersonic drag and sonic boom reduction, where work such as Bedin and Mishin [4] show that thermal and plasma-dynamic effects of EM discharges can reduce aerodynamic drag.

As with the small and large diameter circular toroids, standing waves of magnetic field energy formed over the planar, teardrop-shaped toroid when it was radiating in a current opposing mode. However, the standing wave pattern was much more irregularly distributed and both nodes and peaks were difficult to locate with any precision. Magnetic field strength variation with range was measured in one direction out to 10 meters of distance from the large diameter toroid's center in current-adding and current-opposing modes of operation – as is shown in Figure 9. Consistent data was obtained for current-adding mode but less satisfactory data was obtained for current opposing.

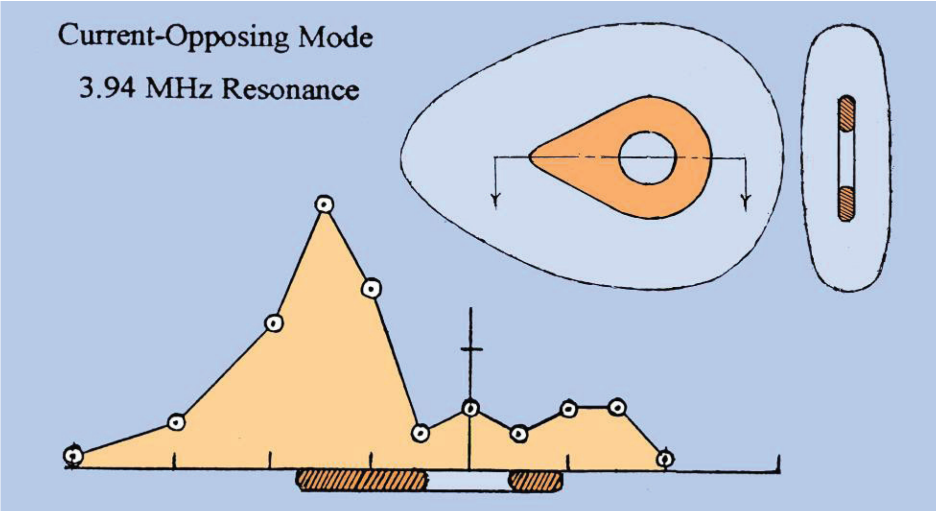

Figure 8. Forward focusing of magnetic field energy from asymmetrical toroids.

Figure 9. Toroid test setup for measuring magnetic field to 10 meters of range.

Figure 10 shows fall-off in EM field intensity from the larger diameter toroid at: a radiating resonant frequency of 1.20 MHz, and in a current-opposing mode. Measured fall-off in signal strength out to 10 m. from the toroid center deviated somewhat from the $1/R^2$ fall-off in signal strength expected for far-field propagation. But all measurements were well inside the near-field of the ~250 m. wavelength associated with 1.2 MHz resonant frequency. A less rapid fall-off than $1/R^2$ occurred at very short distances and more rapid fall-off than $1/R^2$ occurred at the longer distances.

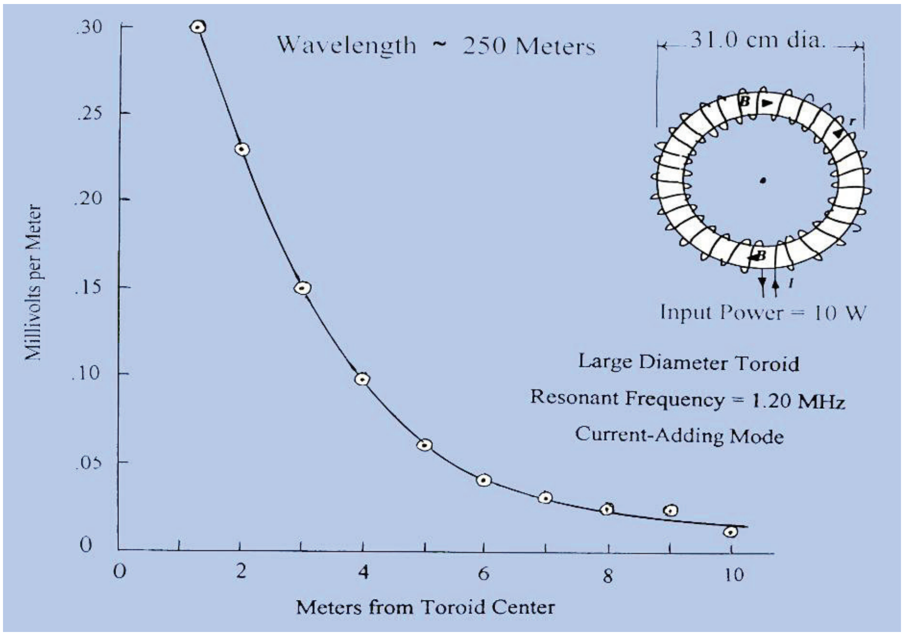

Figure 10. Signal strength fall-off with range for the larger diameter toroid in its current-adding mode.

4. Conclusions From Initial Toroid Experimenal Work

Two brief test series have experimentally explored the ideas of Barrett [2] which suggest that higher order SU(2) EM radiation can be emitted from a toroidal coil when alternating current flows through it at any of the resonant frequencies that can occur for the toroid's geometry. These tests did not prove that SU(2) EM radiation fields were ,indeed, emitted from the tested toroidal coils. But, they revealed interesting and unexpected magnetic phenomena and some appeared consistent with emanation of the SU(2) electromagnetism that was predicted by Barrett.

Our tests could not confirm SU(2) EM field emission from the tested toroidal coils because our ordinary antennas were not capable of detecting the distributed phase patterns of SU(2) A potentials or SU(2) fields. Such detection would have required much more expensive and complex detectors - such as Josephson Junctions - that could detect (but not disturb) the phase patterns associated with states of such fields. Nevertheless, our ordinary U(1) detectors (magnetic probes) detected U(1) magnetic fields outside all tested toroids at resonant frequencies. Such magnetic field detection by our probes would not be expected outside current carrying coils - where only un-detectable U(1) A potentials should exist. But it would be expected if probe presence causes symmetry-breaking of SU(2) fields outside the toroids into U(1) fields. For this would enable detecting the B field components of these U(1) EM fields.

A small number of measurements during the tests indicated significantly stronger signal strength when toroids radiated at resonant frequencies. But there was insufficient test time for detailed exploration of "off-resonance" conditions. This prevented better understanding of what happens electrically inside transmitting toroids and what happens electromagnetically outside them as their resonant frequencies are approached and reached and surpassed. Thus, lack of time for checking or comparing resonance and off-resonance results makes it conceivable that some of our results could ultimately be explained by known U(1) electromagnetism and its U(1) vector and scalar potentials.

However, the most difficult results to explain away are probably those for the current-opposing modes of operation, where counter-flowing alternating currents in contra-wound toroidal coils resulted in no magnetic field whatsoever inside the coils – while, at the very same time, magnetic fields and strong magnetic gradients formed outside them.

5. Future Toroid Testing Work

More testing, involving better field isolation and leakage field considerations, is needed for definitive conclusions on emission of conditioned EM fields from toroidal coils at resonant frequencies and signal benefits they can provide over non-resonant operation. This could be done at places like Hathaway Consulting Services facilities, which now includes an anechoic chamber that will improve the accuracy of any toroid field patterns measured in future testing.

Testing would entail fairly extensive field pattern measurements on only several toroidal coils, with emphasis on an accurate resolution of what happens as resonant frequency is approached and traversed and surpassed. More far-field measurements and determination of the effects of enclosures and magnetic shielding on emitted signal would also be desirable. If results are positive, direct detection of SU(2) fields with Josephson Junctions can also be considered.

Acknowledgment

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